Central Systems

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Central Systems					
Innovations for Existing Plants	21,238	19,081	23,850	+4,769	+25.0%
Advanced Systems	66,502	66,415	74,450	+8,035	+12.1%
Total, Central Systems	87,740	85,496	98,300	+12,804	+15.0%

Description

As part of the President's Coal Research Initiative, FutureGen is a Presidential Initiative to create an advanced, full-scale integrated facility that will utilize advanced coal gasification technology to produce electric power and hydrogen while capturing and sequestering carbon dioxide. The Central Systems Programs is to provide critical research for FutureGen and to dramatically reduce coal power plant emissions (especially mercury) and significantly improve efficiency to reduce carbon emissions, leading to essentially a viable zero-emission coal energy system.

Benefits

The Central Systems subprogram supports DOE's mission to advance national energy security in an economic and environmentally sound manner by developing a cost-effective, high-efficient technological capability to dramatically reduce air pollution from coal-fueled electricity generation plants and carbon emissions to achieve essential zero emissions. In the near term this means having the ability to meet all existing and anticipated environmental regulations at low cost. In the longer term, the aim is to nearly double coal plant efficiencies (from 33% to 60%) at affordable costs of electricity while working towards zero emissions, allowing coal to remain a key strategic fuel for the Nation. The program mission is carried out in support of several key Presidential initiatives including the Coal Research Initiative, Clear Skies Initiative, Global Climate Change Initiative, and the FutureGen Initiative.

Background

The National Energy Policy recommends that the Department continue to develop advanced clean coal technology with a goal of deploying high efficiency coal power plants achieving zero emissions. Further, the President's Clear Skies Initiative is supported by the development of advanced emission control technology and related byproducts as part of the research portfolio under Central Systems. The President's Climate Change Initiative over the longer term is supported through technology for advanced power plants that can nearly double the average efficiency of today's fleet of coal power plants, thereby significantly reducing carbon emissions. The growing national economy relies increasingly on electricity supply that is secure, affordable, and reliable. This is especially true in the face of concerns over national energy security as well as electricity generation market restructuring. In

addition, compliance with more stringent environmental regulations requires reduced emissions from and improved management of freshwater resources used by electric power plants. Further, new technology is needed to develop much cleaner and more efficient plants to replace and augment an aging power generation infrastructure. Electricity demand from both natural gas and coal is projected to increase significantly through the year 2015. (Annual Energy Outlook, 2004).

The program elements for Central Systems include technology developed for existing plants, advanced systems, and zero-emission plants (e.g., FutureGen) are as follows:

- Innovations for Existing Plants (IEP) - The IEP program element has a near- to mid- term focus on improving overall power plant efficiency (thereby reducing carbon emission) and developing advanced cost-effective environmental control technologies for retrofitting to existing powerplants and other coal technologies including those developed in support of the FutureGen initiative such as Integrated Gasification Combined Cycle. The research is also directed at the environmentally sound use and disposal of coal byproducts and at advanced systems and technologies to minimize the impact of electricity production on fresh water availability and quality. The IEP program directly supports the goals and objectives of the President's Clear Skies Initiative that calls for substantial reductions in mercury, NO_x, and SO_2 emissions from power plants. The research also specifically addresses calls for reductions in mercury, NO_x, and SO_2 embodied in recent Clean Air Act proposals by the Environmental Protection Agency. Results of this advanced research are used by those who develop, design, manufacture and operate both existing and advanced systems across the entire spectrum of coal utilization technologies not only to improve efficiencies, but also to improve environmental performance. This program's crosscutting efforts address the cost-effective removal of air pollutants from fossil fueled systems while maximizing the efficient recycling of all by products.

- Integrated Gasification Combined Cycle (IGCC) - The IGCC program supports both the President's Clear Skies Initiative and Climate Change Initiative by enhancing the thermal efficiency of converting coal to electricity, providing the potential for over 50% reduction in CO_2 compared to today's technologies, and through its performance goals of achieving near-zero emissions of SO_2, NO_x, mercury, and other pollutants. The IGCC program conducts research that fosters the development and deployment of zero emission, fuel-flexible gasification-based processes for converting carbon-based feedstocks to electricity, steam, and a broad range of chemicals, including ultra-clean transportation fuels like hydrogen. In order to achieve the full potential of IGCC, significant advances must be made to increase efficiency and reduce the capital and operating and maintenance costs and to improve both the reliability and the overall system availability. In FY 2006, the program will continue to develop technologies for gas stream purification to meet quality requirements for use with fuel cells and conversion processes; to enhance process efficiency; to reduce costs for producing oxygen, and to reduce the cost of hydrogen/carbon dioxide separation. The successful accomplishment of these activities will enhance the commercialization prospects of advanced IGCC technologies for the production of electricity for use by utilities, independent power producers, and other industrial stakeholders.

- Combustion Systems - This program was redirected in prior years to support advanced combustion hybrid concepts for zero-emission compatible plants (FutureGen). In FY 2006, specific technologies

from this category are included in the IGCC activity to enhance the integration of hybrid combustion/gasification concepts, including support for the test activity at the Wilsonville Power Systems Development Facility (PSDF).

- Turbines - The Turbines Program is designed to enable the low cost implementation of the President's Climate Change, Clear Skies, and FutureGen initiatives. The current focus is on developing enabling technology for high efficiency turbines for advance gasification systems that can produce electricity from coal at 45-50 percent efficiency, and creating the technology base for hydrogen turbines that will permit the design of zero emission FutureGen plants with carbon capture and sequestration. The focus is on key technologies needed to enable the development of advanced turbines that will operate with zero emissions, and higher efficiency when fueled with coal derived hydrogen fuels. Developing turbines with superior performance that operate on coal derived synthesis gas and hydrogen is critical to the deployment of advanced power generation technologies such as FutureGen plants. The Turbine Program is an investment in secure U.S. electric power production which is clean, efficient, affordable and is fuel-flexible. These advances in turbine technology will help retain coal's strategic value as a low-cost, abundant, domestic fuel. In FY 2006 work will continue to address technical issues and ultimately provide turbine designs capable of burning up to 100% hydrogen in the 2008 time frame. Funding for the operation of the fuel cell/turbine hybrid simulation facility (HYPER Project) will continue under the Turbines Program.

Detailed Justification

(dollars in thousands)

	FY 2004	FY 2005	FY 2006
Innovations for Existing Plants	**21,238**	**19,081**	**23,850**

The FY 2006 request emphasizes field testing and evaluation of low cost retrofit mercury technology capable of 50-70% mercury capture and removal. In addition, new research will be carried out in the development of advanced combustion and post-combustion NO_x control technologies, as well as the characterization of mercury and other trace metals in coal utilization byproducts from pulverized coal and expanding markets for IGCC materials. Research will continue to focus on technologies and concepts to better manage how power plants use and impact freshwater resources. This research directly supports the goals of both the President's Clear Skies and FutureGen initiatives and recent Clean Air Act emission reduction proposals.

▪ **Super Clean Systems**	**1,466**	**1,465**	**1,000**

In FY 2006, the Super Clean Systems activities will focus on several new projects initiated in FY 2005 to carry out bench and pilot-scale development of advanced combustion and post-combustion NO_x control technology to achieve ultra-low emissions. This research will address operational issues associated with Selective Catalytic Reduction systems to achieve these stringent emission reductions as well as provide options for smaller, older coal-fired boilers in meeting future NO_x regulations under the Clear Skies Initiative and proposed interstate transport

regulations. Research will also be performed to control and optimize the speciation of mercury in the combustion zone. *Participants include: REI, ALSTOM, Fossil Energy Research, and Babcock & Wilcox.*

In FY 2005, Super Clean Systems research focuses on reducing nitrogen oxide (NO_x) emissions from coal-based power plants in direct support of the Clear Skies Initiative. Work will continue on development of ultra low-NO_x combustor for integrated gasification combined cycle systems resulting from FY 2002 Broad Based solicitation. Research will also continue under FY 2004 targeted solicitation to develop advanced combustion NO_x control technology, novel catalysts and non-ammonia reagents for SCR systems, and advanced "smart systems" to achieve a mid-term (2010) emission target of <0.10 lbs/mmBtu and a long-term (2020) target of <0.01 lbs/mmBtu. *Participants include: Argonne National Lab, Precision Combustion, TBD.*

In FY 2004, Super Clean Systems research focused on reducing emissions of primary oxides associated with NO_x and SO_x pollution in support of the Clear Skies Initiative. The work will complete Ultra-low NO_x Burner development, and continue development and pilot-scale testing of novel NO_x control technology concepts selected under the FY 2002 Broad Based Solicitation and under an FY 2003 targeted solicitation. *Participants include: Argonne National Lab, GTI, Praxair, Wiley, Precision Combustion, TBD.*

- **Fine Particulate Control/Air Toxics**..... **13,198** **11,080** **16,211**

The FY 2006 effort will be directed at a comprehensive portfolio of projects to field test advanced mercury control technologies at operating power plants. These technologies, which include sorbent injection, chemical additives, and oxidation catalysts, are capable of achieving 50-70% mercury removal and will focus on units burning low-rank coals. In addition, a third phase of field testing will be initiated, contingent upon the success of ongoing bench and pilot development, involving technologies capable of +90% mercury removal. *Participants include: ADA-ES, UNDEERC, Sorbtech, URS, ALSTOM, EPRI, GE-EERC, Brookhaven National Lab, Argonne National Lab, Lawrence Berkeley National Lab, ATS, TBD.*

In FY 2005, the effort focused on continuation of Phase II field testing of advanced mercury control technologies selected under FY 2003 targeted solicitation capable of achieving 50-70% mercury removal in direct support of Clear Skies Initiative, including a second round of awards made in late FY 2004. Research is directed at lower-rank coals and balance-of-plant issues. Complete pilot-scale testing of novel mercury/multi-pollutant control concepts capable of >90% mercury capture. *Participants include: Brookhaven National Lab, Argonne National Lab, Lawrence Berkley National Lab, ATS, SRI, University of Utah, TVA, TBD.*

FY 2004, In support of Clear Skies Initiative, continued Phase II field testing of advanced mercury control technologies to achieve 50-70% mercury removal directed at lower rank coals and balance-of-plant issues. Continued bench- and pilot-scale development of novel technology to achieve 90%+ mercury capture. Developed fine particulate and acid gas control and sensor

technology selected under FY 2002 solicitation. Continued with more comprehensive modeling assessment of fine particulate and mercury source-receptor relationships. Continued projects selected in FY 2003 to address energy-water issues. *Participants include: Brookhaven National Lab, Argonne National Lab, Lawrence Berkley National Lab, ATS, CONSOL, URS, CMU, SRI, Powerspan, Apogee, TVA, UMD, BNL, LBL, RBD.*

- **In-House Research** **3,911** **3,905** **3,900**

  In FY 2006, mercury sorbents and oxidizing agents to enhance the capture of mercury will be tested at the laboratory scale. Work will also continue in developing a CFD model of mercury emission and control. In addition, the environmental characterization of coal utilization byproducts from the field testing of mercury control technologies will continue. These research activities are in direct support of FutureGen and Clear Skies. *Participants include: NETL.*

  In FY 2005, continue development of novel mercury control concepts and mercury emission characterization using 500 lb/hour combustion unit. Continue CFD modeling of mercury emission and control, issue analysis, by-product characterization, and water-related research in support of FutureGen and Clear Skies. *Participants include: NETL.*

  FY 2004, Research and systems analysis was conducted on novel multi-pollutant control, mercury control and characterization, by-product characterization, and water-related issues in support of zero-emissions for FutureGen and Clear Skies. *Participants include: NETL.*

- **Waste and Water Management** **2,445** **2,440** **2,500**

  In FY 2006, continue assessment of the fate of mercury and other metals, and coal combustion and advanced combustion/gasification byproducts including evaluation of fly ash and scrubber solids from the Phases II Hg Field Testing program, in support of both FutureGen and Clear Skies. Complete advanced concepts and technologies related to power plant use and impacts on quality selected under the FY 2003 targeted solicitation to manage power plant water use, as well as initiate new water management research under a FY 2005 targeted solicitation focused on advanced power plant cooling technology, use of impaired waters, and water recovery and reuse technology. Conduct joint industry/government R&D activities to maximize recycle use of coal utilization byproducts for various market applications, and facilitate technology transfer. *Participants include: USGypsum, UNDEERC, EPRI, Argonne National Lab, TBD.*

  In FY 2005, assess potential environmental impacts of coal combustion and advanced combustion/gasification byproducts and solid residues, focusing on mercury and other trace metals, in support of both FutureGen and Clear Skies. Continue characterization of coal byproducts from Phase II mercury control technology field testing initiated under FY 2004 targeted solicitation. Conduct joint industry/government R&D activities to maximize recycle use of coal utilization byproducts for various market applications, and facilitate technology transfer. Complete development of byproduct treatment and separation technology selected under FY 2003 Broad Based solicitation. Continue advanced concepts and technologies selected under the FY

(dollars in thousands)

FY 2004	FY 2005	FY 2006

2003 targeted solicitation to manage power plant water use. *Participants include: Argonne National Lab, WVU, PPL, UNDEERC, University of Kentucky.*

FY 2004, Continued assessment of environmental impacts of coal combustion and gasification byproducts and solid residues, focusing on mercury and other trace metals. Conducted joint industry/government R&D activities to maximize recycle use of coal utilization byproducts for various market applications, and facilitate technology transfer. Continued development of byproduct treatment and separation technology selected under FY 2003 Broad Based solicitation. Initiated projects selected under the FY 2003 targeted solicitation to maximize water utilization efficiency with minimal environmental impact. *Participants include: WVU, PPL, UNDEERC.*

- **Program Support**..... **218** **191** **239**

Fund technical and program management support.

Advanced Systems..... **66,502** **66,415** **74,450**

Advanced Systems focus on the development of critical enabling technologies and systems for new, cost-competitive plants with increasingly higher efficiencies and inherent ultra-low emissions that support the President's Clear Skies and Global Climate Change, and FutureGen initiatives, leading ultimately to near-zero emission power plants compatible with carbon sequestration.

Integrated Gasification Combined Cycle..... **49,115** **45,805** **56,450**

- **Gasification Systems Technology**..... **28,513** **26,809** **34,341**

Gasification: In FY 2006, the Power Systems Development Unit (PSDF) will focus on assessing the performance of a new char recycle system, a continuous coarse ash disposal system, the Stamet dry coal feeder, and the newly installed synthesis gas recycle system, all focused on improving the reliability and availability of the gasification system with the capability of producing hydrogen. NETL's Transport/Circulating Fluidized Bed facility will be used to support the development of the transport chemical looping gasifiers by evaluating the impact of particle size and size distribution on fluidization characteristics, attrition, and elutriation. Testing of advanced gasification concepts will be continued. Work will continue on developing the chemical looping concept and will focus on optimizing the operating conditions for the various reactor vessels. Testing of advanced feed injectors and the channel wall cooling system will be completed, and the design of the compact gasifier will begin. Novel gasifier/process concepts for enhancing hydrogen and methane yields will continue to be explored at the bench scale. Testing of the optical pyrometer for high temperature measurement device at Tampa Electric's IGCC plant will be completed. Testing of the optical fiber high temperature measurement device will be completed at the Wabash River IGCC plant. Bench-scale testing of an engineering prototype acoustic high temperature measurement device will be conducted in preparation for full-scale

testing at the Wabash River IGCC plant. Complete post mortem analysis of a novel thermocouple assembly removed from service in a commercial coal gasifier and develop 2nd generation device based upon findings. Complete fabrication of commercial size 2nd generation high chromia refractory and install in a commercial coal gasifier. Complete evaluation of metal coatings and coupon tests at the Wabash River IGCC plant.

Gas Cleaning/Conditioning: In FY 2006, R&D will focus on achieving essentially zero emissions from gasification-based systems. Performance tests will be conducted on the Transport Reactor Development Unit (TRDU) to evaluate the improvements in particulate removal efficiency using an electrostatic barrier filter and newly developed sorbents for removal of mercury and other trace metals. Sorbent materials for chloride removal will be identified and prepared in an industrial scale unit in collaboration with a catalyst manufacturer and will be subjected to bench-scale testing to determine performance for achieving near-zero contaminant levels. In conjunction with an industrial partner, a new sulfur sorbent will be tested in a bench-scale unit to evaluate its ability to achieve <500 ppb sulfur. A promising mercury sorbent will be subjected to absorption/regeneration cycling in simulated synthesis gas to determine its ability to achieve >90% removal at moderate process temperatures. Continue development of the second generation catalyst for the Selective Catalytic Oxidation of Hydrogen Sulfide (SCOHS) technology to achieve <500 ppb sulfur. The detailed design of a skid-mounted unit for testing of the SCOHS technology will be completed. The CFD model for sorbent regeneration in a transport desulfurizer will be completed, integrated with the absorption model, and the combined model validated using data from slipstream testing at Eastman Chemical. Testing of the hot cyclone-filter hybrid concept for particulate control on a slipstream from the Wabash River IGCC plant will be completed. Continue development of multi-contaminant control technologies to reduce capital cost through reduction of process units. *Participants include: SCS, NETL, UNDEERC, ConocoPhillips, Boeing, ALSTOM, GTI, CrystaTech, Entertechnix, VPI, ARC, SRI, Eastman, GE.*

Gasification: In FY 2005, the primary focus of the Power Systems Development Unit (PSDF) will be on preparation of the facility for testing advanced zero-emission compatible (Vision 21) modules while continuing to characterize the operation of the oxygen-blown transport gasifier on a range of coal feedstocks including lignite. Validation of the CFD model for the transport gasifier will continue using performance data from the PSDF, the Transport Reactor Development Unit (TRDU), and the cold model at NETL.

Gas Cleaning/Conditioning: In FY 2005, R&D will focus on achieving near-zero emissions from gasification-based systems. Operation of the Gas Process Development Unit for obtaining scale-up data for the design of transport desulfurizer using the RT13 sorbent at moderate temperatures will be completed. Validation of the transport desulfurizer CFD model will be completed using performance data from the GPDU and integrated testing with a 2.5 ton/day pilot-scale coal gasifier. Continue R&D to develop advanced concepts for removing mercury,

ammonia, and chlorides to near-zero levels suitable for use in fuel cell and synthesis gas conversion applications. Construction of a skid-mounted unit of the Selective Catalytic Oxidation of Hydrogen Sulfide (SCOHS) process will be initiated. A go/no decision on field testing of the Single-step Sulfur Reduction Process (SSRP) will be made based on prior experimental and economic performance. *Participants include: SCS, NETL, UNDEERC, Fluent, RTI.*

Gasification: In FY 2004, continued to develop and test the oxygen-blown transport gasifier and associated particulate control devices at the PSDF to reduce cost and improve reliability of gasifier technology. Primary focus at the PSDF was on oxygen-blown operations to provide options for producing hydrogen and capturing CO_2 and multi-fuel capability to enhance the applicability of the technology. Validated the oxygen-blown transport gasifier CFD model using data generated from the PSDF and the Transport Reactor Development Unit (TRDU) using various coal feedstocks. Utilized the TRDU to pre-screen coal feedstocks, alternative feed systems, and process conditions to provide guidance for testing at the PSDF. Developed advanced materials for refractories and thermocouples to improve refractory performance and improve gasifier reliability. Tested prototype refractory bricks in a commercial coal gasifier to demonstrate performance under actual operating conditions, and begin to install a novel high temperature measurement device to demonstrate improved gasifier performance and process control. Continued development of other advanced technologies such as burner flame monitoring, refractory wear monitoring, diffusion coatings, etc. to improve the reliability, availability, and performance of gasifiers. Investigated fundamental pre-competitive technology issues and needs to improve gasification process performance and reliability through the Gasification Technology Research Consortium.

Gas Cleaning/Conditioning: In FY 2004, efforts were directed to obtaining near-zero emissions from gasification based systems including construction of a gas cleanup module at PSDF to pave the way for testing of advanced modules for carbon capture and near-zero emission gas cleaning technologies. Developed advanced sorbents for achieving ultra-low sulfur levels of all contaminants at moderate temperatures. Operated the Gas Process Development Unit's (GPDU) using the RT13 sorbent at moderate temperatures in the transport mode to provide design data for scale-up of the technology. Continued validation of the transport desulfurizer CFD model using data from the GPDU and data generated in a pilot-scale test facility integrated with a coal gasifier. Developed the novel Selective Catalytic Oxidation of Hydrogen Sulfide (SCOHS) technology and begin bench-scale evaluations for proof-of-concept testing of the technology to demonstrate ultra-low sulfur emissions at reduced cleanup costs. *Participants include: SCS, NETL, UNDEERC, Fluent, RTI, Albany, Alstom, GE, Boeing, VPI, SRI, Entertechnix.*

- **Systems Analysis/Product Integration** **3,706** **3,944** **3,944**

In FY 2006, work will continue on assessing the economics of advanced process concepts such as chemical looping and advanced gasification concepts, multi-contaminant control technologies,

etc. The economics of the Transport Reactor Integrated Gasification (TRIG) process with CO_2 capture will be developed. Studies will be conducted to establish performance targets for novel process concepts in the R&D program such as alternative systems that can potentially capture carbon dioxide along with raw gas impurities without the need for gas clean up system to reduce cost. Engineering support will be provided as needed for the development and evaluation of the FutureGen project. *Participants include: NETL, RDS, TAMS, Mitretek, Parsons, SCS, GTC.*

In FY 2005, work will continue on assessing the economics of advanced near-zero emissions process concepts and establishing performance targets for novel process concepts in the R&D program. Work at the PSDF will focus on developing integration strategies for advanced process concepts and developing experimental programs, cost, and schedules for testing the various technologies. The final engineering designs for the Early Entrance Coproduction Plant project for the production of electricity, fuels, and hydrogen will be prepared. The standardized design of a 25 MWe bituminous coal IGCC plant for industrial applications and a 250 MWe lignite IGCC for utility applications will be completed. Engineering support will be provided as needed for the development and evaluation of the FutureGen project. The update of the worldwide gasification database with the latest plant project announcements will be completed, and the sixth gasification environmental workshop will be held in Knoxville, TN. *Participants include: NETL, RDS, Mitretek, SCS, Childress, GTC.*

In FY 2004, completed engineering designs of Early Entrance Coproduction Plants for clean fuels like hydrogen and high efficiency power productions as pre-Vision 21 concepts. Continued systems analyses for research guidance and product outreach activities. Updated the worldwide gasification database. Established size of standardized IGCC plants from market analysis and begin design of modular unit to reduce plant cost, shorten plant startup schedule, and improve system reliability. *Participants include: NETL, CTC, E2S, Mitretek, SFA, Pacific, Texaco, Parsons, WMPI, GE, KBR, Praxair.*

- **Vision 21** **16,392** **14,594** **17,600**

In FY 2006, the planar design advanced air separation membranes will be demonstrated at the 3-5 tons per day using full-size modules and achieving 95% purity. Enhanced reliability of the full-size modules will be enhanced through advanced process control techniques. The detailed design of the 25 TPD pre-commercial unit will be completed. The PSDF will focus on preparing the facility to test advanced hydrogen production and separation technologies. Discussions will be held with appropriate technology developers to establish process requirements and costs for evaluating their technologies with coal-derived synthesis gas. Technologies to be considered for testing include advanced water gas shift, K25 membrane, the CO_2 hydrate process, and a polymer membrane for bulk CO_2 and H_2S removal. New metal alloy materials and cermet membrane materials will be developed for H_2/CO_2 separation and subjected to lab-scale permeation tests. The design of an engineering scale process development unit to test the tubular H_2/CO_2 membranes at commercially relevant operating conditions will commence. The K25 H_2

membrane will begin scale-up in preparation for testing at a gasification site. Continue construction of the 2.5 megawatt equivalent CO_2 hydrate slipstream test for testing on coal-derived synthesis gas. Bench-scale testing of novel ionic liquids for the separation of CO_2 from fuel gas will be conducted to evaluate solubility and mass transfer of CO_2 into the liquids. Field testing of first generation ammonia, arsenic, and mercury removal sorbents will be completed at a gasification site on coal-derived synthesis gas at moderate temperatures to demonstrate ability to achieve near-zero contaminant levels. Additionally, a H_2/CO_2 membrane that selectively removes CO_2 and H_2S will also be demonstrated on coal-derived synthesis gas. A process unit to demonstrate the novel sorbent-based polishing technology will be designed for integrated testing with a coal gasifier to demonstrate performance for achieving near-zero levels of contaminants. Additionally, innovative concepts to reduce the potential plant investment costs, such as development of raw syngas shift and separation will be assessed. *Participants include: APCI, Concepts NREC, Ceramatec, GE, PSU, Penn, Nexant, RTI, Medal, Protech, Eastman, SRI, , NETL ORNL, Eltron, Coorstech, Noram, Sud Chemie, SCS.*

In FY 2005, efforts will focus on the development of novel technologies that lead to ultra-high efficiencies, the production of hydrogen for ultra-clean fuels, and the elimination of all environmental issues that present barriers to the continued use of coal, including reductions of SO_2, NO_x, CO_2 particulates, and trace elements such as mercury, arsenic, cadmium, and selenium. Laboratory testing of improved materials for membrane-based air separation technologies and life testing of commercial membrane elements will be completed. The construction of the 1-5 ton/day air separation membrane unit will be completed, and testing of full-scale membrane modules will commence. Development of novel process concepts for the production of hydrogen and the capture of CO_2 for sequestration will continue. Work on developing improved membranes for hydrogen/ CO_2 separation will continue with focus on developing and optimizing the membrane fabrication process and addressing performance characteristics under actual process conditions. The K25 membrane will begin further development and scale-up for testing at PDSF and Eastman Chemical on coal-derived synthesis gas. A polymer-based membrane unit for bulk CO_2 and H_2S removal will be designed an constructed for testing at Eastman Chemical. An engineering analysis of the CO_2 hydrate process will be completed, and experimental work will focus on achieving equilibrium in the separation reactor. Testing of an advances sulfur sorbent in a transport reactor as a slipstream from the coal gasifier at Eastman Chemical will commence to prove long-term performance and stability of the sorbent. The design and construction of skid-mounted units for mercury, ammonia, and chloride control will begin for testing at Eastman Chemical. Continuous unit testing of the Unmixed Fuel Processor will begin to demonstrate integrated performance of the gasifier. *Participants include: APCI, Praxair, ANL, Concepts NREC, Ceramatec, GE, PSU, Penn, Nexant, RTI, Medal, Protech, IGT, Siemens-Westinghouse, NETL, Eltron, Coorstech, Noram, Sud Chemie, SIR, KBR.*

In FY 2004, to achieve the Vision 21 program goals, developed novel technologies that lead to ultra-high efficiencies, near-zero emissions, carbon capture for sequestration and the production

(dollars in thousands)

FY 2004	FY 2005	FY 2006

of hydrogen for ultra-clean fuels and powers. Scaled-up and tested ceramic membrane modules for advanced air separation at the 1-5 ton/day scale to reduce the cost of oxygen and pave the way for the economical capture of CO_2. Began initial planning of 50 ton/day membrane modules for integration with a gasifier and gas turbine. Investigated improved membrane materials, fabrication techniques, and module design for H_2/CO_2 separations to address capture of CO_2 and for producing low-cost hydrogen from coal. Conducted life testing of advanced ceramic hydrogen membranes and develop conceptual process designs. Constructed a polymer hydrogen membrane module for integrated testing with a pilot-scale coal gasifier to address performance under actual process conditions. Constructed skid-mounted unit for the development of the low temperature hydrate technology to demonstrate effective carbon management by separating hydrogen and carbon dioxide and begin preliminary site evaluation for integration with a gasifier. Investigated advanced gas cleaning technologies to meet near-zero emission requirements in response to the Clean Skies Initiative. Began testing of an advanced sulfur cleanup technology integrated with a pilot-scale coal gasifier to evaluate process performance under realistic conditions. Constructed skid-mounted process units for mercury, ammonia, and chloride control for possible integrated testing with a pilot-scale coal gasifier. Completed conceptual design and economic analysis of a novel coal gasification concept for producing hydrogen and sequestration-ready CO_2 that has potential for cost reductions over conventional approaches. *Participants include: APCI, Praxair, ANL, Concepts NREC, Ceramatec, GE, PSU, Penn, Bechtel, LANL, RTI, Medal, Protech, IGT, Siemens-Westinghouse, NETL, GEERC, ITN, Eltron, Coors, INEEL, Sud Chemie, SRI, ORNL, McDermott, KBR.*

- **Program Support**..... **504** **458** **565**

  Fund technical and program management support.

Combustion Systems **4,812** **5,227** **0**

- **Gas Stream Cleanup** **1,312** **0** **0**

  In FY 2006 and FY 2005, there are no activities planned.

  In FY 2004, completed projects including qualification of candle filters for pressurized applications; design of bench scale CFBC unit for coal/biomass/solid waste feeds; and optimization of catalyst and furnace operations to achieve low-NO_x emissions.

- **Advanced Hybrid Combustion**..... **3,450** **5,175** **0**

  In FY 2006, there are no activities planned.

  In FY 2005, efforts will be re-focused on the development of novel technologies in oxygen combustion; catalytic unmixed combustion of coal; high pressure coal combustion kinetics and continuous pressure feeds for solid feedstocks needed to meet the requirements of advanced zero

(dollars in thousands)

FY 2004	FY 2005	FY 2006

emissions power generation systems. *Participants include: ALSTOM, GEGR, Stamet, Fluent, Inc., Western Kentucky University, General Electric.*

In FY 2004, efforts focused on the development of novel technology in hybrid combustion-gasification; catalytic unmixed combustion of coal; high pressure coal combustion kinetics and continuous pressure feeds for solid feedstocks to validate the engineering, economic and environmental viability to meet Vision 21 performance targets. *Participants include: Foster Wheeler, ALSTOM, GEGR, Stamet, Fluent, Inc.*

- **Program Support**..... **50** **52** **0**

Fund technical and program management support.

Turbines **12,575** **15,383** **18,000**

- **Next Generation Turbines** **12,447** **15,229** **17,820**

In FY 2006, the Turbine Program will continue with work initiated in FY 2004 and FY 2005 to address technical issues and ultimately provide turbine designs capable of burning 100% hydrogen in the 2012 time frame. Through the FY 2005 Hydrogen Turbine solicitation, new work will continue to optimize machine performance for FutureGen that results in higher efficiencies and lower emissions of NO_x. NO_x reduction through catalytic combustion and fuel premixing will continue and should be approaching single combustor-can tests applicable to large frame machines. In addition, new work will continue on advanced turbine designs and subsystems for zero-emission, sequestration-ready power systems suitable for FutureGen applications. Work will continue and new work initiated through the University Turbine Systems Research Consortium concerning aerodynamics, materials, heat transfer and combustion of coal derived syngas and hydrogen fuels. NETL will continue the simulation and validation of combustion phenomena associated high hydrogen content fuels. *Participants include: GE, Siemens Westinghouse, Clemson-University Turbine Systems Research Consortium, NETL, ORNL, TBD*

In FY 2005, the Office of Fossil Energy will transition the Turbine Program, which is focused on modifying the designs of existing advanced turbines for applications to coal derived synthesis gas, to a Hydrogen Turbine Program. The Hydrogen Turbine Program is designed to support the successful deployment of FutureGen type power systems. FutureGen plants will enhance the continued use of coal our Nation's largest source of fossil fuel and provide options for the capture and sequestration of carbon dioxide. The technical performance challenges of coal-based sequestration ready power plants that use and produce hydrogen create new opportunities for turbine based power systems. These opportunities will be identified and explored through the FY 2005 Hydrogen Turbine Solicitation.

The FY 2005 program will build upon work initiated in FY 2004 to address technical issues and ultimately provide turbine designs capable of burning up to 100% hydrogen in the 2012 time

frame. The relevant technical issues are driven by the need to increase machine efficiency while at the same time reducing NO_x emissions. The lower heat content, higher flame speed and high post combustion moisture content of hydrogen present significant technical challenges to development of highly efficient and clean burning combustion turbines for FutureGen applications. New work will be initiated to further resolve technical issues associated with the use of hydrogen fuels from FutureGen power plants. Technology development requirements for highly efficient, zero emission and sequestration ready coal-based power plants presents a challenging set of technical issues. The program is positioned to focus resources on these issues which require a better understanding of materials, aerodynamics, heat transfer and combustion fundamentals. Ultimately, as these issues are resolved, full-scale components and systems can be tested in FutureGen type facilities.

FY 2005 work will focus on turbine performance improvement by resolving technical issues that can then be applied to F- or G-class machines for high (>65%) hydrogen combustion. Part of this performance enhancement will consider the full integration with the balance of plant subsystems such as the air separation unit and steam cycle. It is expected that work to improve efficiency will address better thermal barrier coatings, better methods for blade cooling, fuel premixing, optimizing the mass throughput, and aerodynamics, and extending or realizing the full torque limitations of existing machines. Work will continue with GE, Siemens Westinghouse, Precision Combustion, Inc., and others to resolve NO_x emissions and efficiency improvements for turbines operated in FutureGen type plants. Work will continue and new work will be initiated through the University Turbine Systems Research Consortium concerning aerodynamics, materials, heat transfer and combustion of coal derived syngas and hydrogen fuels. NETL will continue the simulation and validation of combustion phenomena associated with high hydrogen content fuels. Funding for the operation of the fuel cell/turbine hybrid simulation facility (HYPER Project) will continue under the Turbines Program. *Participants include: GE, Siemens Westinghouse, Precision Combustion, Clemson-University Turbine Systems Research Consortium, NETL, ORNL, TBD.*

Work initiated in FY 2004 continued on high hydrogen fuel combustion for NO_x reduction and efficiency improvements. This work included GE's efforts to assess premixing issues for NO_x reduction associated with high hydrogen fuels and integration issues of F-class machines in coal-based plants. Work by Siemens Westinghouse and Precision Combustion, Inc., continued to explore catalytic combustion for NO_x reduction in high hydrogen fuels applications. GE continued to identify opportunities for system efficiency improvements for FutureGen type plants through the optimization of turbine operation and integration. Work continued and new work was initiated through the University Turbine Systems Research Consortium concerning aerodynamics, materials, heat transfer and combustion of coal derived syngas and hydrogen fuels. NETL continued the simulation and validation of combustion phenomena associated with high hydrogen content fuels. Funding for the operation of the fuel cell/turbine hybrid simulation facility (HYPER Project) continued under the Turbines Program. P*articipants include: GE,*

(dollars in thousands)

FY 2004	FY 2005	FY 2006

Siemens Westinghouse, Praxair, Florida Turbine Tech., EPRI, NETL, Clemson-University Turbine System Research Consortium, NETL, ORNL, TBD.

▪ **Program Support**	**128**	**154**	**180**
Fund technical and program management support.			
Total, Central Systems	**87,740**	**85,496**	**98,300**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Innovations for Existing Plants	
▪ **Super Clean Systems**	
An emphasis on increasing funding for mercury removal research as a priority will stretch out the research pace on NO_x	-465
▪ **Fine Particulate Control/Air Toxics**	
Increased funding reflects the emphasis in mercury control research as a high priority area in IEP and includes a large portfolio of projects to field test advanced technologies at operating power plants. In addition, a third phase of field testing will be initiated involving technologies capable of +90% mercury removal. This program directly supports the President's Clear Skies Initiative by developing advanced, low-cost mercury control technologies that will be needed to achieve the goals of the initiative	+5,131
▪ **In-House Research**	-5
▪ **Waste and Water Management**	
As water usage increasingly becomes an issue for plant operations (especially in the West) competitive research on advanced technologies to minimize water usage will be pursued. Increase in funding will be used to support selections under FY 2006 solicitation directed at advanced technologies and concepts to minimize freshwater use by coal-fired power plants	+60
▪ **Program Support**	+48
Total, Innovations for Existing Plants	**+4,769**

	FY 2006 vs. FY 2005 ($000)
Advanced Systems	
Integrated Gasification Combined Cycle (IGCC)	
▪ **Gasification Systems Technology**	
Increase in Gasification Systems Technology includes increased level of effort in testing of advanced process components at the PSDF; increased effort on the development of advanced gasifier components and instrumentation, and increased efforts on the development of novel multi-contaminant control technologies. This program supports the goals of the President's Clear Skies and Global Climate Change Initiatives and his National Energy Plan, goals that require technological advanced in gasification technology and cannot be resolved with legislation or regulation alone	+7,532
▪ **Systems Analysis/Product Integration**	
Increase in level of effort on testing of hydrogen production and separation technologies at the PSDF as part of the Hydrogen Initiative and complete testing of gas cleaning technology at Eastman Chemical	+3,006
▪ **Program Support**	+107
Total, Integrated Gasification Combined Cycle	**+10,645**
Advanced Combustion	
▪ **Advanced Hybrid Combustion**	
The program will come to an orderly termination using prior year funding	-5,175
▪ **Program Support**	-52
Total, Advanced Combustion	**-5,227**
Turbines	
▪ **Next Generation Turbines**	
Increase in Turbines includes additional work needed to address technical issues for turbines designed with the capability to burn up to 100% hydrogen.	+2,591
▪ **Program Support**	+26
Total, Turbines	**+2,617**
Total, Advanced Systems	**+8,035**
Total Funding Change, Central Systems	**+12,804**